Tire Pressure Inflation System

Sachin Joji Mathew[1],Sibin Thomas[2]
Varghese,VishnuVijayan[3],Yedukrishnan[4], G.Anilkumar[5]
[1234]UG Student, [5]Associate Professor, Saintgits College of Engineering
[12345]Department Of Mechanical Engineering, Saintgits College of Engineering Kerala
E-mail:- [1]sachin.joji@gmail.com,[2]sibin91t@gmail.com,[3]vishnuv677@gmail.com,
[4]yedukrishnan464@gmail.com,[5]anilkumar.g@saintgits.org

Abstract–Tire pressure plays an important role in ensuring safe and economical driving. Improperly inflated tires can affect stopping distance increases the chance of tire delaminating, reduces the handling characteristics which in turn affects the control of vehicle. Even then, many vehicles with under inflated tires are observed to be on the road due to the unawareness of the fact that properly inflated tires can safe tire life up to 20%, save fuel from 4% to 10%, increase braking efficiency up to 20%, lightens the steering system and can help in ease self-steer. In every month, there is a pressure drop of 10KPa to 20KPa in a car. Drop of each 10KPa is equivalent to adding a 70Kg person into the car and causes over loading due to virtual passenger condition in the car. To address this problem, an automatic tire pressure inflation system has been idealized to ensure correct pressure is inflated into the tires regardless of the setting on the pressure source. The device will alert the user upon reaching the appropriate pressure by a LED indication. The system consists of a storage tank, dc compressor, pressure switch, battery and solenoid valve. Air taken from the atmosphere is compressed in the compressor and is transferred to the tire when the pressure reduces from the recommended value.

Key word:- Inflation Pressure, Pressure switch ,Pressure guage, Solenoid control valve, DC Compressor.

I.INTRODUCTION

Tire pressure plays an important role in ensuring safe and economical driving. Proper tire inflation pressure improves fuel economy by 4% to 10%, reduces braking distance, improves handling, and can safe tire life upto 20% which is nine months more of its life span, while under inflation creates overheating, increases the chance of tire delaminating, which could lead to a sudden tire failure, increase the wear of tire treads which will lead to a higher chance of aquaplaning in wet, cause longer stopping distances and reduce the control of vehicles which can lead to accidents. Approximately 3/4 of all automobiles operate with at least one underinflated tire. The main causes of under inflation are natural leakage, temperature changes, and road hazards.

Drivers typically do not check tire pressure unless they notice unusual vehicle performance. Visual checks are often insufficient to determine under inflation.

In 2000, the U.S. Transportation Recall Enhancement, Accountability, and Documentation Act (TREAD) requested that the National Highway Transport Safety Authority (NHTSA) investigate the implementation of a pressure drop warning system on vehicles. Beginning with 2006 models, all passenger cars and trucks in the United States are required to have tire-pressure inflation systems (TPMSs). A TPMS is a driver-assist system that warns the driver when the tire pressure is below or above the prescribed limits. Tires are designed and built with great care to provide thousands of miles of excellent service. But for maximum benefit they must be maintained properly. Therefore a method of how to ease the users to inflate their tires is engineered and invented. Automatic tire pressure controller has been idealized to ensure correct pressure is inflated into tires regardless of the setting on the pressure source. The device will alert the driver upon reaching the appropriate pressure by a LED indication. This device will often attracts many users especially ladies who often being the second driver who are always unsure of the pressure in their tires.

The most important factors in tire care are:

· Proper Inflation Pressure
· Proper Vehicle Loading
· Proper tire Wear
· Regular Inspection
· Good Driving Habits
· Vehicle Condition

The Benefits of Proper Inflation:

With the right amount of air pressure, you will achieve optimum tire performance. This means your tires wear longer, save fuel and help prevent accidents. The "right amount" of air is the pressure specified by the vehicle manufacturer, which may be different on the front than the rear tires on your

particular model car or light truck. The correct air pressure is shown on the tire placard (or sticker) attached to the vehicle door edge, door post, glove box door or fuel door. If your vehicle doesn't have a placard, check the owner's manual or consult with the vehicle manufacturer, tire manufacturer or your local tire dealer for the proper inflation. The tire placard tells you the maximum vehicle load, the cold tire air pressures and the tire size recommended by the vehicle manufacturer. If you don't take proper care of your tires, the results can be serious. Most tire companies are either supplying a handbook or are molding a safety warning right onto the tire sidewall. A typical warning is shown on this page.

As you see, it points out that serious injury may result from tire failure due to under inflation or overloading. Motorists are strongly advised to follow the vehicle owner's manual or the tire placard in the vehicle for proper inflation and loading.

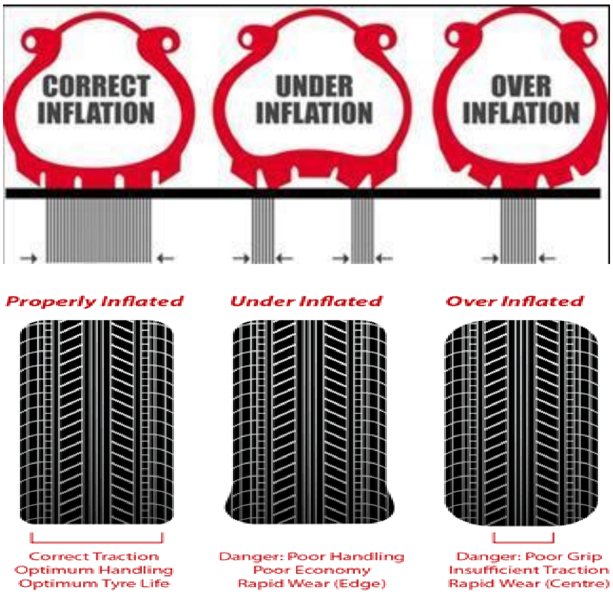


Fig.1.1 Tire under different conditions

placard in the vehicle for proper inflation and loading.

II SIGNIFICANCE OF TYRE PRESSURE

A. EFFECT OF UNDERINFLATED TIRE

Severe defects and danger could occur onto underinflated tires where they are exposed to overload and excessive heating conditions. Fig.2.1 and Fig.2.2 clearly show the respective phenomena which occur due to this condition.

· Overload Condition

The phenomena and analysis of underinflated tires which cause terrible overloading onto automobile is clearly shown in Fig.2.1.

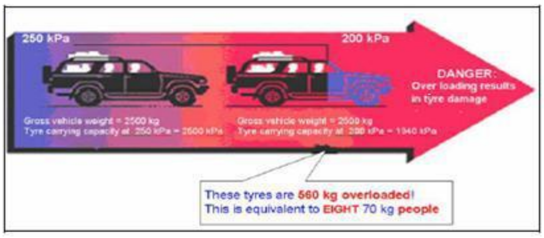
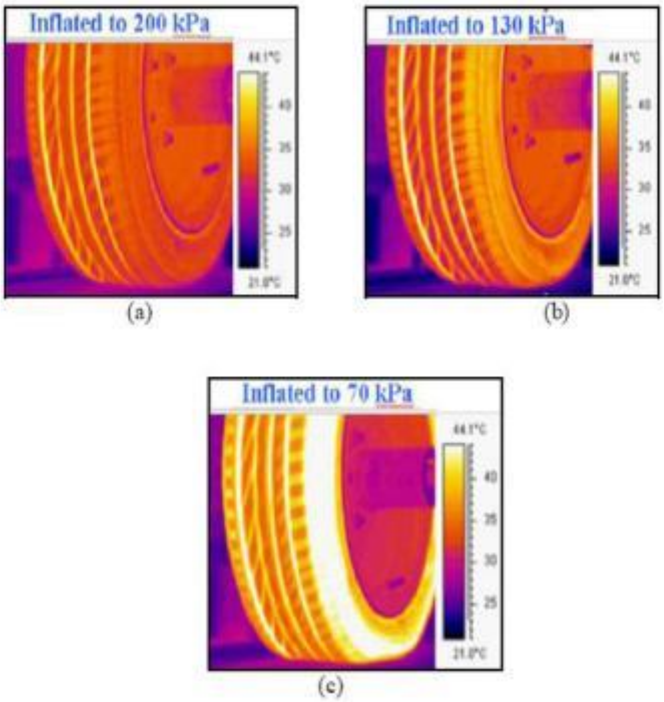


Fig.2.1 Overload Effect

· Heated up Condition



Under inflated tires cause excessive heat dissipation

Fig.2.2 Thermal Imaging of Tire Pressure

where it increases wear rate, easily damages the tire and exposed to risk of explosion. Thermal imaging of tires with different inflated conditions (a),(b),(c), are shown in Fig.2.2 Some of the other effects related to under inflated tires are as described below:

-Endurance

Driving on under-inflated tires reduces their endurance capabilities, leading to deterioration that could even result in a rapid deflation. 7 psi (0.5 bar) or more under inflated results in danger

-Road Holding

With under- inflated tires, the vehicle's steering is less precise. If a bend can be taken at 62 mph (100 km/h) at a tire pressure of 29 psi (2.0 bar), this speed drops to 54 mph (87 km/h) at 15 psi (1.0 bar), or about 8 mph (13 km/h) less. Lower pressures results worse road holding

-Aquaplaning

If tire pressures are 30% below the recommended pressure there is a sharp increase in the risk of aquaplaning. Lower pressures results higher risk of aquaplaning

-Braking

In addition, tests show that braking distances from 56 mph (90 km/h) to 43 mph (70 km/h) are 40 metres at 29 psi (2.0 bar) but 45 metres at 15 psi (1.0 bar), that's 5m longer. 15 psi (1.0 bar) under inflation results 5m longer braking distance

-Fuel Consumption

Tires under inflated by 15 psi (1 bar) have increased rolling resistance leading to around 6% greater fuel consumption.

B. EFFECT OF TIRE PRESSURE ON ROLLING RESISTANCE

Fig.2.3 Variation of Tire Pressure on Rolling Resistance

Rolling resistance can be defined as the force that acts in the opposite direction that makes the tire less efficient. The graph showing the variation of tire pressure on rolling resistance is as shown in the figure below.

C. VARIATION OF MILEAGE WITH TIRE PRESSURE

National Research Council estimates reducing tire rolling resistance to 10%, promises 1-2% fuel savings for ~220 million light vehicles in U.S. Annual national fuel savings estimated at up to 2 billion gallons of gasoline which is equivalent to taking about 4 million cars and light trucks off the road. Average individual car annual savings estimated at about 10 gallons/year. Average savings

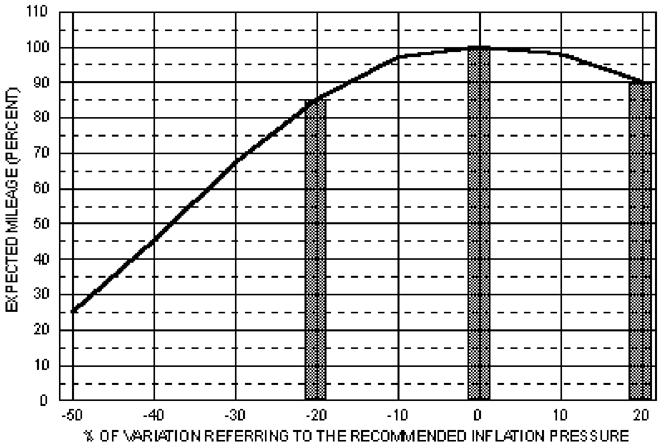


Fig.2.4 Mileage Versus Tire Pressure

Rolling resistance which is caused by deformation of the tire in contact with the road surface is brought about as a result of the deviations in the tire pressures of a vehicle. The increases in the rolling resistance of the tire have also resulted in the increase of energy needed in order to move a vehicle.

III WORKING OF THE SYSTEM

Apparatus consist of a DC compressor and 12 v battery arrangements. DC compressor is operated with the help of this 12v battery. The maximum pressure that the compressor can develop is 300psi/20.7 bar. The compressed air is then stored in a storage tank. A pressure gauge is provided to check the pressure in the tank periodically. A non-return valve is used to connect the DC compressor with the storage tank. Compressed air is given to the 2/2 solenoid valve inlet. The pressure switch is used to sense the tire pressure. The required tire pressure is set by the pressure switch reading. This pressure switch is used to sense the current pressure and this output signal is given to the solenoid valve.

Whenever the tire pressure is below the set valve the pressure switch activate the solenoidvalve.The compressed air goes to the tire with the help of quick release coupling which is used to rotating the wheel freely. The quick joint coupling is used to connect the freely rotating wheel with the other stationary components such as the tubing of solenoid valves etc.

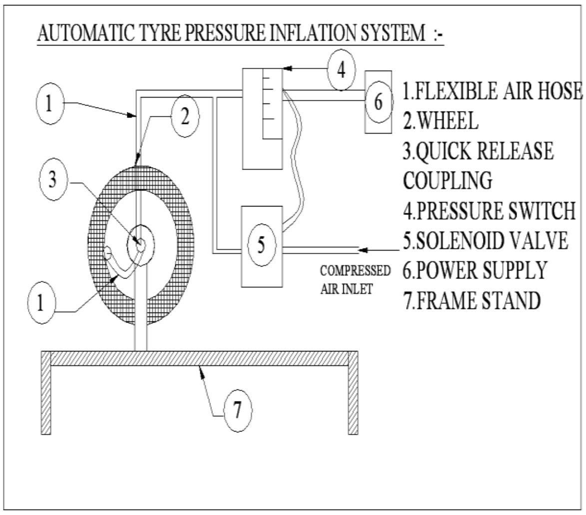


Fig.3.1. Schematic View of Tire Pressure Inflation System

The required pressure is filled then the pressure switch will be deactivated the solenoid valve so that the tire pressure will be maintained in constant level. Whenever there is a drop in pressure from the recommended pressure, this solenoid valve will be activated and required air flow takes place into the tire to regulate the pressure. This is the basic working of Automatic tire pressure regulation system. The entire system can be well understood by viewing the detailed sketch shown below.

When driving a car with TPMS, make sure that you know how it will communicate a drop in tire pressures to you. There may be several different ways, such as a light on the dashboard, an audio signal or a diagram of the car with the tire suffering the decreased pressure highlighted. If it is by a light on the dashboard then make sure you understand what it looks like as there have been several ways developed to communicate a decrease in tire pressure.

A driver should still perform regular tire checks of his vehicle, which involve testing the pressure with an accurate gauge, checking the tire wall for damage, and making sure that the tread is not worn. A tread depth of 1.6 mm is the legal

minimum although 3mm and above provides significantly greater safety benefits.

A. Major components of the system

Pressure switch

A pressure switch is a form of switch that closes an electrical contact when a certain set pressure has been reached on its input. The switch may be designed to make contact either on pressure rise or on pressure fall. Another type of pressure switch detects mechanical force; for example, a pressure-sensitive mat is used to automatically open doors on commercial buildings. Industrial Pressure Switch (IPS) is an electromechanical device that senses changes in pressure and provides electrical contact closures at predetermined pressure values.

Fig.3.2 A hydraulically formed seamless Phosphor

Generally they are small in sizes. Such small cracks are known to propagate due to fluctuating stress conditions. If these propagating cracks remain undetected and reach .
Micro-switch is at desired pressure settings. The cut-in and cut out points are adjustable over the entire range. IPS Pressure Switch may be used to activate an alarm or may directly control the process. In an alarm application, the switch protects valuable equipment by an audible signal. Indirect control application, the switch can be linked electrically to other equipment, for trip or interlock.

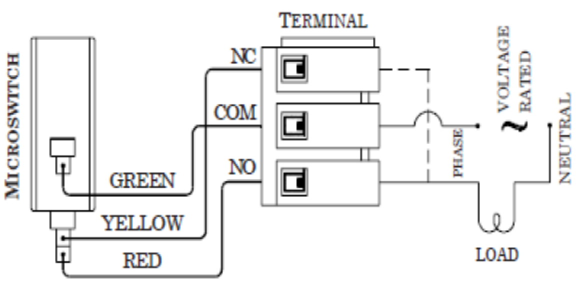


Fig.3.3 Circuit Diagram for Pressure Switch

Quick Joint Coupling

A coupling is a device used to connect two shafts together at their ends for the purpose of transmitting power. Couplings do not normally allow disconnection of shafts during operation, however there are torque limiting couplings which can slip or disconnect when some torque limit is exceeded.

The primary purpose of couplings is to join two pieces of rotating equipment while permitting some degree of misalignment or end movement or both. By careful selection, installation and maintenance of couplings, substantial savings can be made in reduced

Fig.3.4 Quick Joint Coupling

maintenance costs and downtime. So in order to connect the rotating wheel and stationary solenoid valve , we use a quick joint coupling here.

Solenoid Control Valve

Solenoid control valves control the way the air passes and used for controlling the commencement, termination and direction of air flow. Depending on the number of paths the air is allowed to take, directional valves are termed as two way, three way, and four way or multi way valves. The different number of ways by means the number of controlled connections of the valve, inlet connections to the compressed air supply. The Outlet connection is given to the air consumer and exhaust connection is given to the atmosphere.
Here pressure switch is in normally closed condition, therefore current flows through the coil in solenoid valve and thereby the plunger of valve will be lifted up due to the electromagnetic field created in the system. Thus required air flow to tire takes place through the valve until desired set condition is arrived.
When the pressure switch is in normally open condition, therefore current will not flows through the coil in solenoid valve and thereby the plunger of valve will be lowered in the absence of air.

Fig.3.5 Solenoid Valve

Pressure Gauge

Instruments used to measure pressure are called pressure gauges or vacuum gauges. A manometer could also refer to a pressure measuring instrument, usually limited to measuring pressures near to atmospheric. The term manometer

is often used to refer specifically to liquid column hydrostatic instruments.

A vacuum gauge is used to measure the pressure in a vacuum-which is further divided into two subcategories, high and low vacuum (and sometimes ultra-high vacuum). The applicable pressure ranges of many of the techniques used to measure vacuums

Fig.3.6 Pressure gauge

have an overlap.

Hence, by combining several different types of gauge, it is possible to measure system pressure continuously from 10 mbar down to 10−11 mbar. The pressure in the system can be directly obtained in the units of bar and pounds per square inch (psi).

DC Compressor

The DC compressor used here takes the current from the inbuilt 12v battery in the vehicle itself. The maximum pressure that the compressor can develop is about 300psi or 20.7 bar. This DC compressor is used for storing the compressed or high pressure air in the storage tank, which is further used for inflation. DC compressor helps in maintaining the required pressure in the storage tank of the system.

Fig.3.7 DC Compressor

Descriptions:

Dimensions: 16 x 13 x 8cm
Maximum Output: 300 PSI/20.7 bar
Robust and Durable Design
22" Nylon Air Hose.

Storage Tank

The compressed air is then stored in a storage tank. A pressure gauge is provided to check the pressure in the tank periodically. A non-return valve is used to connect the DC compressor with the storage tank. The storage tank and the DC compressor will be placed in the vehicle whichhelps in maintaining the recommended pressure in the vehicle whenever the pressure in the vehicle tire drops. This is done with the help of a solenoid valve pressure switch assembly, where the valve opens to make the air flow from storage tank to the tire whenever pressure drop occurs.

Fig.3.8 Storage Tank

Wheel Arrangement

The simple wheel is fixed to the frame stand. Rotation of the wheel is obtained by using a pulley motor arrangement. Therefore tire pressure regulation can be well explained during the running condition of wheel.

Frame Stand

This is a supporting frame and is made up of mild steel. It forms the base of the entire components of the system.

B. Working Model

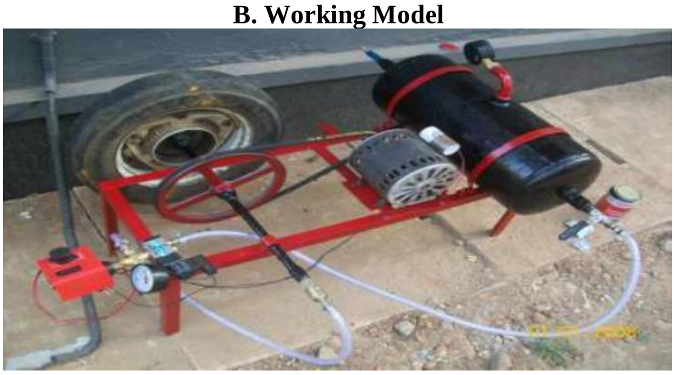


Fig.3.9 Automatic Tire Pressure Inflation System

IV DESIGN OF BEARING AND SELECTION OF SHAFT

An axle is a central shaft for a rotating wheel or gear .On wheeled vehicles the axle may be fixed to the wheels, rotating with them. Bearings are provided at the mounting points where the axle is supported. The design is based upon maximum stress theory and torsion and bending theory.

Specifications of motor and pulley are as follows:

Motor

Speed of motor N1 =1440 rpm
Diameter D1 =30 mm
Power P1 =0.5 hp =373 W

Pulley

Speed N2 =201 rpm
Diameter D2 =240 mm
Thickness of belt = 5mm

Slip in the belt

$$\frac{N2}{N_1} = \frac{[D1 + t]}{[D_2 + t]} \times \frac{[100 - S]}{100}$$

$$\frac{201}{1440} = \frac{[30 + 5]}{[240 + 5]} \times \frac{[100 - S]}{100}$$

S = 2.29 %

Assume power transferred from motor to pulley be same due to low value of slip

$$P_1 = \frac{2\pi N_1 T_1}{60}$$

$$T_1 = \frac{373 \times 60}{2\pi \times 1440}$$

$$T_1 = 2.47 \text{ Nm}$$

$$P_2 = \frac{2\pi N_2 T_2}{60}$$

$$T_2 = \frac{373 \times 60}{2\pi \times 201}$$

T_2 = 17.72 Nm
Coefficient of friction, μ = 0.3
Angle of contact, θ = 220

t_1 and t_2 are the tensions on tight and slack sides

$$\frac{t_1}{t_2} = e^{\mu\theta}$$

$$\theta = 220 \times \frac{[\pi]}{180}$$

$$t_1 = 3.164\, t_2$$

$$T_2 = (t_1 - t_2) \times r_2$$

$$(t_1 - t_2) = \frac{17.72}{0.12}$$

$$R_a + R_{bv} = 49.05 + 7.85 + 216.2 \sin 20 - 68.5 \sin 20$$

$$R_a + R_{bv} = 107.4 \text{ N}$$

For vertical plane $\Sigma M_a = 0$,

$R_{bv} \times 0.29 = -49.05 \times 0.1 + 7.85 \times 0.1 + 216.2 \sin 20 \times 0.1 - 68.5 \sin 20 \times 0.1$

$$R_{bv} = 3.21 \text{ N}$$

$$R_a = 104.19 \text{ N}$$

For horizontal plane $\Sigma M_a = 0$,

$$[t_1 \cos 20 + t_2 \cos 20] \times 0.1 = R_{bh} \times 0.29$$

$$R_{bh} = [216.2 + 68.5] \cos 20 \times \frac{0.10}{0.29}$$

$$R_{bh} = 92.25 \text{ N}$$

For thick cylinder

$$\frac{t}{d_i} > \frac{1}{15}$$

Let $\frac{t}{d_i} = \frac{1}{15}$

Torque equation

$$T_2 = \frac{\pi}{16} \times \tau \times d_o^3 \times [1 - k^4]$$

Where $k = \frac{d_i}{d_o} = \frac{d_i}{d_i + 2t}$, T_2 = 17.72 Nm

Assume τ (for shaft material) = 50 N/mm^2
From torque equation, d_o of the shaft = 16.6 mm

Bending moment equation

$$M = \frac{\pi}{16} \times \sigma_b \times d_o^3 \times [1 - k^4]$$

Where, M = 4.905 Nm
Bending stress (for shaft material), σ_b = 100 N/mm^2
From bending moment equation
d_o= 8.59 mm
Suitable shaft outer diameter d_o= 16.6 mm

Selection of bearing

Net load on bearing, R

$$R = [R_{bh}^2 + R_{bv}^2]^{0.5}$$

Life of the bearing

$L_{hrs} = \frac{10^6 \times L_{mr}}{60 \times N_2}$, expected life in hours (L_{hrs} =8000 hrs)

$L_{mr} = \frac{60 \times 201 \times 8000}{10^6}$ = 96.48 millions of revolutions

$L_{mr} = \frac{C^m}{R^m}$, m=3 (for ball bearing)

Dynamic load carrying capacity, $C = L_{mr}^{0.33} \times R$

$$C = 96.48^{0.33} \times 92.3$$
$$C = 423.3 \text{ N}$$

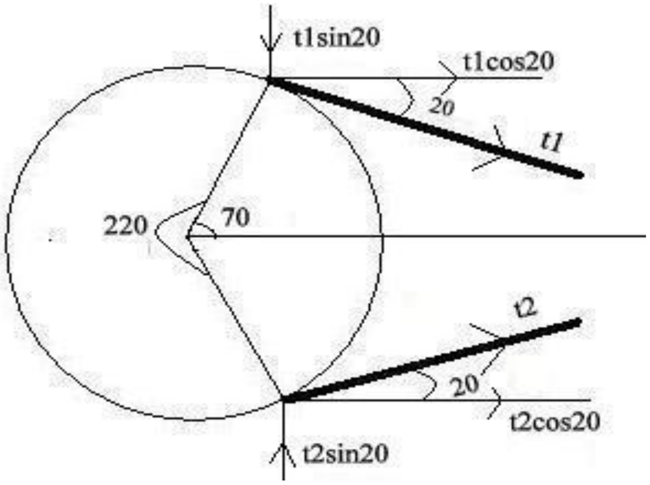


Fig. 4.1 Forces acting on the shaft

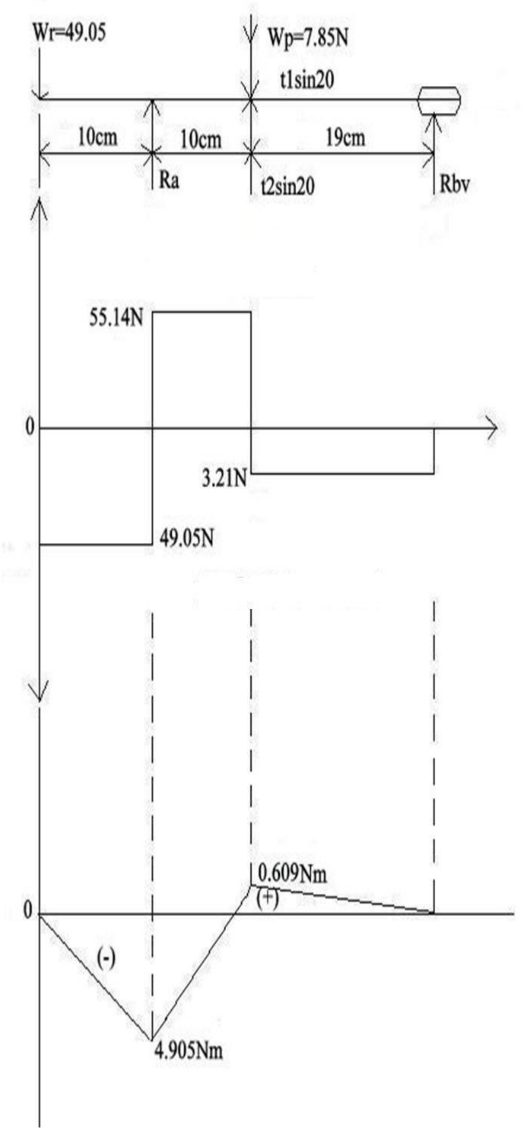


Fig. 4.2Shear Force And Bending Moment Diagram

Bearing designation

SKF 6203 and corresponding dynamic load carrying capacity C = 1680 N

Therefore design is suitable.

V RESULT AND DISCUSSIONS

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Proper tire pressure thus always helps to improve the tire life, attains greater braking efficiency, improved ride quality and cargo safety due to reduction in the vehicle vibrations, improved vehicle mobility due to the increase in traction when tire pressures are lowered. When the required pressure in the tire is reached, the buzzer will indicate it to the driver and the solenoid valve will shut off the air supply to the tire. Thus on implementing the Tire pressure inflation system to the four wheeler vehicle, the system will helps the driver to regulate and maintain proper pressure inside the tires.

The development of Tire pressure inflation system (TPIS) has proven that the users inflate their tires more frequently at home over the weekends and found to be as an easier application towards sustaining correct tire pressure at all times. Its ability to relief excessive air from over inflated tire is also fully utilized as hooking up Automatic tire pressure inflation system to the value without any other devices are taken as advantage. The tire pressure inflation system is working with satisfactory conditions.

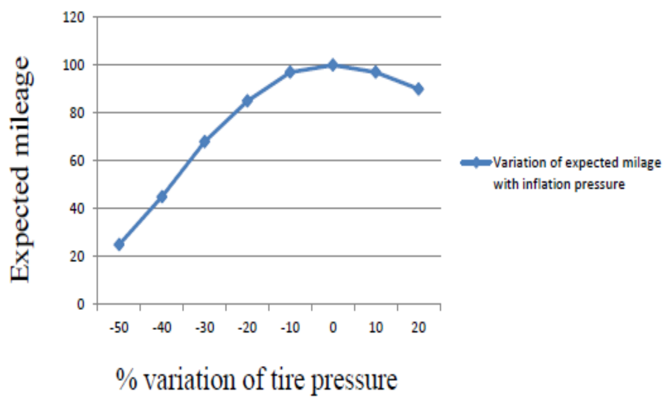

Fig.5.1 Graph for Milage and variation in pressure

Rolling resistance which is caused by deformation of the tire in contact with the road surface is brought about as a result of the deviations in the tire pressures of a vehicle. The increases in the rolling resistance of the tire have also resulted in the increase of energy needed in order to move a vehicle. This has therefore contributed to the rise of the fuel flow rate as a result of changes in the tire pressure.

The mileage versus % variation of tire pressure is shown in Fig. 5.1. Increased fuel efficiency can be obtained by installing TPIS. The system maintains zero variation in tire pressure, thus increase in mileage can be expected irrespective of load conditions. On implementing the TPIS, an increase in the life of new drive tires is possible and an increase in life of rethreaded tires. The number of tires that were damaged after the implementation of the TPIS will be greatly reduced. A

reduction in maintenance cost can be expected due to the implementation of TPIS. Lowering the tire pressure to match the road surface decreases vibration levels of the vehicles.

CONCLUSIONS

A Tire Pressure Inflation System has been designed and fabricated to regulate tire pressure. Thereby a large amount of energy is saved and it results in a smooth operation of vehicle. The development of TPIS has proven that the users inflate their tires more frequently at home over the weekends and found to be as an easier application towards sustaining correct tire pressure at all times.

Automatic tire pressure inflation systems have many advantageous benefits in the transportation industry. These benefits include, improved vehicle mobility due to the increase in traction when tire pressures are lowered, improved ride quality and cargo safety due to the reduction in vehicle vibrations when the correct tire pressure is used for a particular road condition, reduced road maintenance because sediment production is limited and lowered road construction costs, increased fuel efficiency and a considerable increase in the tire life of vehicles.

The Tire Pressure Inflation System is working with satisfactory conditions. Available facilities, materials and expertise have been fully utilized for the design and the fabrication of the system.

The efficiency curves obtained under different load conditions has to be matches with that of theoretically plotted efficiency curve.

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